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USAARU REPORT NO. 68-1

DEVELOPMENT OF A PAINT SCHEME FOR INCREASING HELICOPTER CONSPICUITY

By

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ERRATA SHEET

U. S. Army Aeromedical Research Laboratory Report 68-1, "Development of a Paint Scheme for Increasing Helicopter Conspicuity," by Bynum, Bailey, Crosley and Nix, dated September 1967.

	Action
Page 7, Table 1	Reverse position two (Black-Gloss White) and position three (White-Orange Yellow) schemes. The numbers remain unchanged.
Page 8, Table 2	Reverse the B and C, i.e., position B should correspond to the White-Orange Yellow and position C the Black-Gloss White.
Page 8, Para 1, Line 3	Change "Gloss White-Black-Scheme" to "White-Orange Yellow scheme."
Page 9	"* See Table 2 for Scheme Descriptions" should read "See Apparatus, page 5, for Scheme Description"
Page 9, Para 4, Line 3	Change "black-gloss white" to "white-orange yellow."
Page 9, Para 4, Line 5	Change "black-white" to "white-orange yellow"

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DEVELOPMENT OF A PAINT SCHEME FOR INCREASING HELICOPTER CONSPICUITY

I. INTRODUCTION

A heavy saturation of helicopter traffic in a training, or combat environment overloads present systems for controlling the available air space to prevent mid-air collisions. Student pilots and instructors working in such a demanding environment are required to devote a large portion of their instructional period to outside-the-aircraft activities, namely, looking for other aircraft. It is reasonable to assume that this time-sharing produces decrements in performance and decreases the quality of instruction in addition to the stress that results from the constant threat of mid-air collision.

One of the more practical and obvious approaches to the problem is to make the aircraft more visible at near and intermediate ranges. At the same time the development of sophisticated electronic devices is being conducted to warn of aircraft in the immediate vicinity. However, these devices are in the development stage and the problem requires, at least, immediate attention and an interim solution. Some system for enhancing conspicuity, e.g., painting, is therefore indicated.

The problems of aircraft conspicuity and detectability with paints have been documented (Evans, 1959; Crain & Siegel, 1960; Siegel, 1961; Siegel and Crain, 1961; Federman & Siegel, 1962; Cook, Beazley & Robinson, 1962; Siegel and Federman, 1965; and Siegel, Lanterman, Lazo, Gifford & Provost, 1966). For the most part, however, the work was done on model fixed wing aircraft under controlled conditions. The results of these laboratory and field tests have indicated that:

1. Fluorescent paints have a lower threshold for visual detection than ordinary paints.

2. Detectability is a function of the size and shape of the painted area.

3. Stimuli presenting two contrasting colors were more effective than monochromatic stimuli.

4. Chromaticity and luminance are important variables in detection and both must be considered.

Further, there would appear to be some psychological advantage for the fluorescent paints. The results of an interview with 96 Navy pilots (Federman and Siegel, 1962) indicated that the pilots believed that high visibility paints contribute to aircraft detectability and visibility. They favored fluorescent paints from this point of view and cited many instances in which they attributed the detection of other aircraft solely to the presence of these paints.

The problems inherent in aircraft conspicuity would seem to hold across the various models and types of aircraft that have been tested. However, the helicopter presents a set of unique problems insofar as location and pattern of paints are concerned. Observation and utility-type helicopters present varying masses, ranging from helicopter fuselages that are well defined in terms of mass to those which have but a metal frame for the major portion of the aircraft. In addition, Army helicopters have paint schemes on the fuselages which vary according to type and mission of the aircraft. The light, observation helicopters are either painted entirely orange or are painted olive drab with or without fluorescent red-orange (FR-O) markings. The utility aircraft are painted olive drab with some having FR-O markings on the nose and sections of the tail boom. Because of the mission requirements of Army aircraft in combat support, the color of the fuselage is a fixed variable.

Therefore, because of the varying masses of the different types of helicopters and because the paint scheme is more or less fixed insofar as fuselage is concerned, the logical choice for paint location is the rotor. This selection is feasible for more than this reason, however. When the rotor system is at operating RPM it gives the appearance of a "dish" rather than "x" number of blades rotating counterclockwise. Further, since the rotor diameters range from 35 feet on the H-13 to 48 feet on the UH-1, a considerable "mass" is available for viewing. The problem resolves itself to: Where should the paint be located and what colors and paint scheme are more practical as well as conspicuous?

First, the paint location problem has been studied and the information derived can be applied to this particular problem. A study by Cook, et al., (1962) indicated that, for maximum conspicuity, high-brightness paints should be placed on the upper surfaces of aircraft, and low-brightness paints should be placed on the lower surfaces. Since the lower surface of the rotor is black, this would seem to suffice. In addition, adverse visual stimulations could occur in the cockpit as a result of the interaction of the rotor paint markings and navigation light reflections as well as light reflections from other sources. These stimulations could be a serious hazard to flight.

Since most of the conspicuity work to date has been on fixed wing aircraft, the transfer of the data to rotary wing configurations was unknown. In addition, there are many colors and paint schemes that could have been used. However, the literature also offered some help in this regard. Lazo (1954) conducted a study for the Navy in which he investigated color schemes to improve propeller noticeability. His recommendations included a scheme that would maximize brightness contrasts when viewed against dark backgrounds and one that would maximize hue contrasts when viewed against bright backgrounds. Since the backgrounds for the upper surfaces of the rotor blades would be relatively darker, the maximizing of the brightness contrasts seemed to be the appropriate avenue of approach. And, as cited above, the work of Cook, et al. (1962) substantiates Lazo's recommendations.

Lazo's final recommendations were based on several tests involving a scheme in which the propeller tips were painted; a scheme copying the present design for helicopter tail rotors; and a reversal of the helicopter tail rotor design. His final recommendations, based on the study, indicated the scheme that reverses the helicopter tail rotor scheme was the best for noticeability of propellers. This scheme is 6" of white at the tip, 6" of bright red, 6" of white, a strip of black to within 6" of the propeller hub, and finally, 6" of bright red. The basic reason for the reversal of the scheme on the tail rotors was due to the comparative backgrounds of the two. That is, the tail rotor is generally viewed against a brighter background such as sky, etc., while the propeller is generally viewed against a darker background. Since this is true in most cases, the tips of the tail rotors are painted a darker color to contrast with the lighter background while the recommended color for the tips of the propellers is white to contrast with the darker backgrounds.

Lazo's study pointed to the fact that white was the color that provided the maximum brightness contrast in all cases except those with a very bright sky. Therefore, it seemed reasonable to incorporate white in any proposed scheme. Also, since studies have demonstrated that the psychological and physical properties of fluorescent paints in and near the red-orange spectrum recommend these paints, it seemed equally reasonable to incorporate a fluorescent red-orange.

As to schemes, Lazo's was functional and it was felt that this would be a reasonable plan for any future painting schemes.

Crosley (1967) conducted a study utilizing actual aircraft for stimulus presentations. He used the paint scheme dimensions outlined by Lazo and applied them proportionally to the upper surfaces of the main rotor systems of 4 UH-1D helicopters. Crosley's study recommended the application on each blade

of white, FR-O, white, black, and FR-O in that order. A second choice was white, yellow-orange, white, black, yellow-orange. The white, red, white, black, red scheme currently used on tail rotors was not as conspicuous as these two.

Crosley's work did not compare colors with non-painted aircraft. Therefore, although one would assume that painted aircraft rotors would be more conspicuous than non-painted rotors, no empirical evidence warranted this conclusion.

Problem

The present study was designed to investigate the following:

1. Is there a difference in conspicuity of painted and non-painted rotor blades on helicopters?

2. What colors will be more conspicuous when applied according to the scheme developed by Lazo?

Research Hypotheses

H_1 - The six related paint schemes were not drawn from six identically distributed populations.

H_2 - Pilots and non-pilots were not drawn from identically distributed populations.

II. METHOD

Subjects

Forty Army aviators were randomly divided into two groups consisting of twenty pilots and twenty observers per group. No subject had participated in any prior studies involving conspicuity of aircraft.

Apparatus

Six TH-13 observation helicopters were utilized as the test vehicles. They were painted in the following schemes: (All schemes begin at the tip and progress inboard.)

A. 3'2" white, 3'2" FR-O, 3'2" white, 4'4" black, 3'2" FR-O.

B. White, orange-yellow, white, black, orange-yellow in the same dimensions as (B) above.

C. Gloss white, black, gloss white, black, gloss white in the same dimensions as (A) above.

D. Codit white, black, codit white, black, codit white in the same dimensions as (A) above. (Codit is a retro-reflector paint typically used on highway signs.)

E. One blade black on the entire upper surface, the other blade painted with a strip of gloss white from the tip 8' inboard.

F. Unpainted.

Procedure

The study was conducted in two sessions on consecutive Saturdays. Twenty subjects reported to a briefing room and were given a description of the task and were assigned to one of two observer helicopters either as a pilot or observer. The pilots were instructed to do all the flying. Observers were told to sit in the co-pilot's seat but to do no actual flying. They were merely to observe and make their judgments. Thus, differences between pilots and non-pilots could be assessed.

The method of Pair Comparisons was used to present the stimuli (Guilford, 1954). The test aircraft were presented in counter-balanced order after Ross (1934).

The general procedure was as follows:

The test aircraft were lined up on two pads designated as X and O, with one pair of helicopters at each pad and the third pair holding on the side-line, awaiting their signal to line up on one of the two pads. One observer

helicopter was lined up behind the pair at pad X and one observer helicopter was lined up behind the pair at pad O. Upon a signal from a controller the pair of test helicopters started a normal take-off and climb from pad O. As per instructions, these helicopters began a climbing right or left turn to an altitude of 300 feet (take-off direction depended on the wind, but it was desirable to have all aircraft fly over the same terrain). They continued in a circular pattern which had its farthest point approximately 1/2 mile from the take-off pad. Twenty seconds after the pair departed, the observer helicopter behind them took off, executed a climbing turn to an altitude of 200 feet above the pair (i.e., 500 feet) and maintained a distance of 50 feet to 1/2 mile above and to the rear of the test aircraft.[1] The observers were asked to compare the two aircraft as they flew over the representative terrain and during the approach and landing. Upon landing, the observers were handed a response sheet by an individual riding in the jump seat. They chose the aircraft which was more conspicuous to them and then handed the response sheet to the assistant. Meanwhile, the test aircraft had changed their relative positions and pads according to a pre-set plan. The observer helicopters always flew from the same pad while the test aircraft were required to shift positions and pads for the proper pairings.

In this procedure, four observers viewed the fifteen possible pairs and then four new observers took their positions according to their assignments.

The time required to present the fifteen pairs to four observers was approximately 50 minutes flying time.

III. RESULTS AND DISCUSSION

Table I shows the mean proportions and T scores for the six-point schemes. The mean proportions are defined as the proportion of total first place choices over possible first place choices for the six schemes. Multiplying the mean proportions by 100 will yield the percentages of first place selections out of 200 possible first places.

[1]Distances in this study were chosen arbitrarily. Time available was a factor to be considered. It was felt that these relative distances would offer reasonable comparisons while staying within the time limits allocated.

TABLE I

Mean Proportions and T Scores for the Paint Schemes Tested

SCHEME	MEAN PROPORTION	T SCORE
White - FR-O	.9650	68.1190
Black - Gloss White	.6650	54.2610
White - Orange Yellow	.5400	51.0040
Black - Codit White	.4600	48.9960
Black Tip - White Tip	.3700	46.6810
Non-Painted	.0000	00.0000

In order to test the hypothesis that the pilots and non-pilots were drawn from identically distributed populations, a Chi Square test was used. The results indicated that the X^2 obtained was not significant and thus the null hypothesis could not be rejected.

A Friedman two-way analysis of variance was applied to the data. Scores were assigned to the schemes on the basis of first choices by each subject. The X_r^2 for paint schemes was significant ($p \leq .001$). Therefore the null hypothesis that these schemes represented k related samples from identically distributed populations was rejected.

Because the Friedman ANOV compares all treatment ranks taken together, no inferences could be made regarding treatments when compared with each other, two at a time. Kirk (Chapter 13, in press) describes a test devised by Nemenyi which is a non-parametric analogue to the a posteriori t-test following a significant F-test. Table 2 represents a matrix indicating the significant differences between treatment compared two at a time using Nemenyi's method.

TABLE 2

SIGNIFICANCE OF LEVELS OF PAINT SCHEMES

	PAINT SCHEME					
	A	B	C	D	E	F
A	-	$p \leq .05$	$p \leq .05$	$p \leq .05$	$p \leq .05$	$p \leq .05$
B	-	-	NS	NS	$p \leq .05$	$p \leq .05$
C	-	-	-	NS	NS	$p \leq .05$
D	-	-	-	-	NS	$p \leq .05$
E	-	-	-	-	-	$p \leq .05$
F	-	-	-	-	-	-

A - White, FR-O
B - Black - Gloss White
C - White, Orange Yellow
D - Black - Codit White
E - Black Tip - White Tip
F - Non-painted

Table 2 indicates that the scheme incorporating FR-O and white was significantly different from all other paint schemes compared two at a time. The gloss white-black scheme was significantly different from the black tip-white tip rotor system and from the non-painted system. All other comparisons indicate that all painted systems were significantly different when compared to the non-painted system but otherwise there were no significant differences in the ranks of these systems.

Table 3 is a comparison of mean proportions and T-scores for the paint schemes.

TABLE 3

COMPARISON OF PAINT SCHEMES ON TWO DAYS

		PAINT SCHEME					
		A	B	C	D	E	F
Day 1	MP	.95	.74	.52	.44	.35	.00
	T	66.45	56.43	50.50	48.49	46.15	00.00
Day 2	MP	.98	.59	.56	.48	.39	.00
	T	70.54	52.28	51.51	49.50	47.21	00.00

* See Table 2 for Scheme Descriptions

These studies were run on two consecutive Saturdays. Some comments are therefore in order regarding meteorological variables.

The first Saturday was a typical summer day with early morning low ceilings which rose as the morning progressed. The ceiling could be described as broken to overcast with numerous cumulous formations and thundershowers in the immediate vicinity.

The second Saturday was what may be described as a typical summer day. A cold front had passed through the area the night prior to testing and this Saturday would be described as CAVU.

It is interesting to note the differences in rankings on the two days as seen in Table 3. On Day 1 the ambient light was considerably less due to the clouds. Here the FR-O (A) still was ranked first, but the black-gloss white (B) received a respectable score. However, with more light as in Day 2 the FR-O was enhanced while the black-white scheme was of less value. This could be a function of reflected light both from the background and the rotor systems. At any rate, there was little loss of conspicuity as a result of the darker day for the

FR-O. This points to the value of using white and FR-O in combination to take advantage of the enhancement properties of both.

IV. CONCLUSIONS

The following conclusions are warranted on the basis of this study:

1. Of the paint schemes tested, the combination white-fluorescent red-orange scheme is preferred.

2. Any paint scheme is preferred to a non-painted scheme.

3. There were no significant differences in the ratings of pilots and non-pilots in this study.

As a result of this study, it is clear that several related questions need attention. This study involved pilots' decisions regarding stimuli to which they were actively attending. The question follows: Would this scheme serve to call attention to an aircraft in close proximity? In other words, what is the value of this paint scheme in a target detection paradigm?

Further, what would be the effect of this scheme on aviators while engaged in formation flying? Would there be severe reactions of a type that could cause an accident or incident? Again, if there are reactions, could they be compensated for by training, instruction, etc.? Admittedly these are questions to which solutions are needed.

A program designed to evaluate these problems is now being devised.

As mentioned previously, time restrictions dictated relative distances of the test and observer aircraft to some extent. Later studies will be included which will test color effectiveness in the target acquisition paradigm at different altitudes and visual angles.

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